Constraining AGN Feedback and SMBH vs. Bulge Growth Through the Galaxy Formation Era

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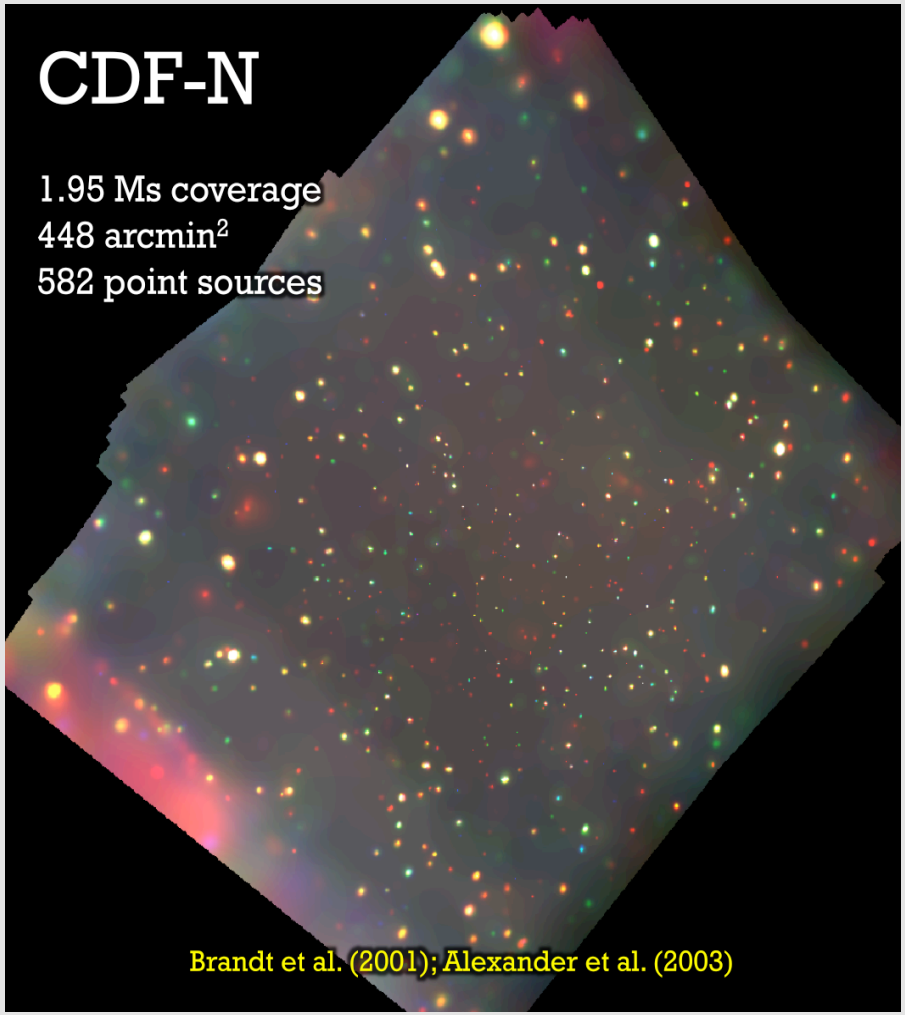
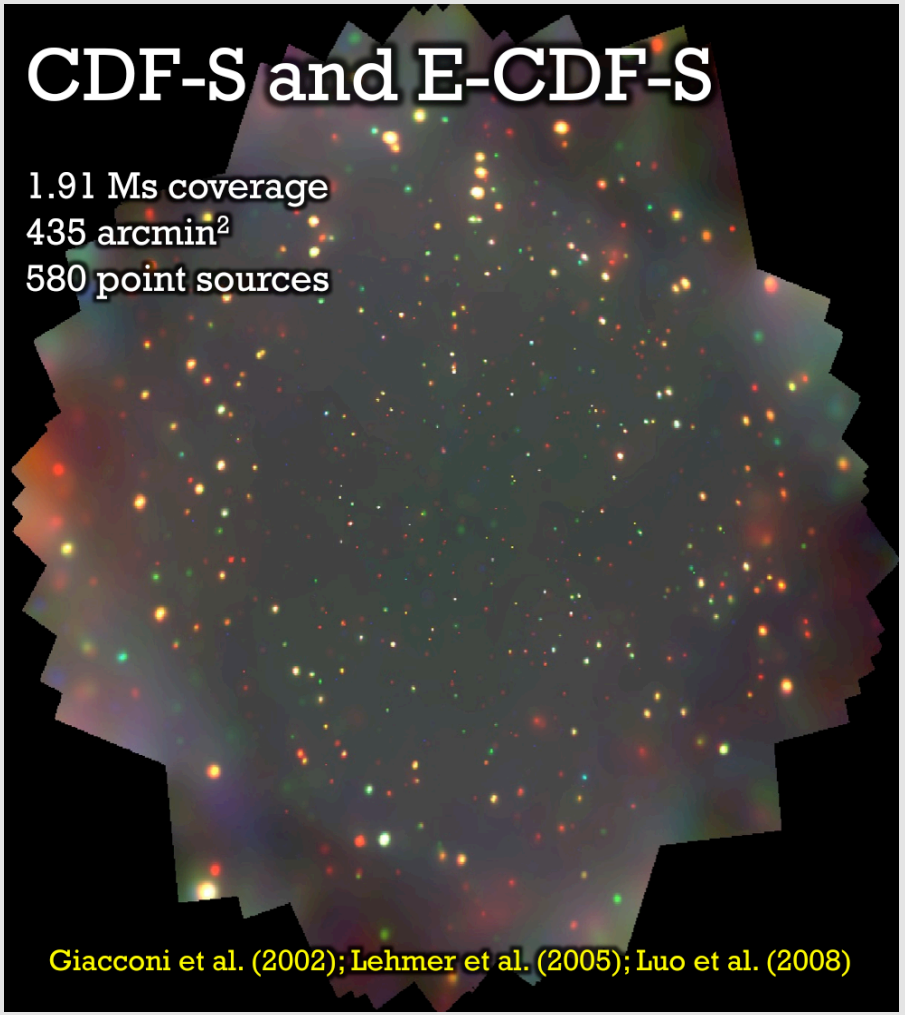
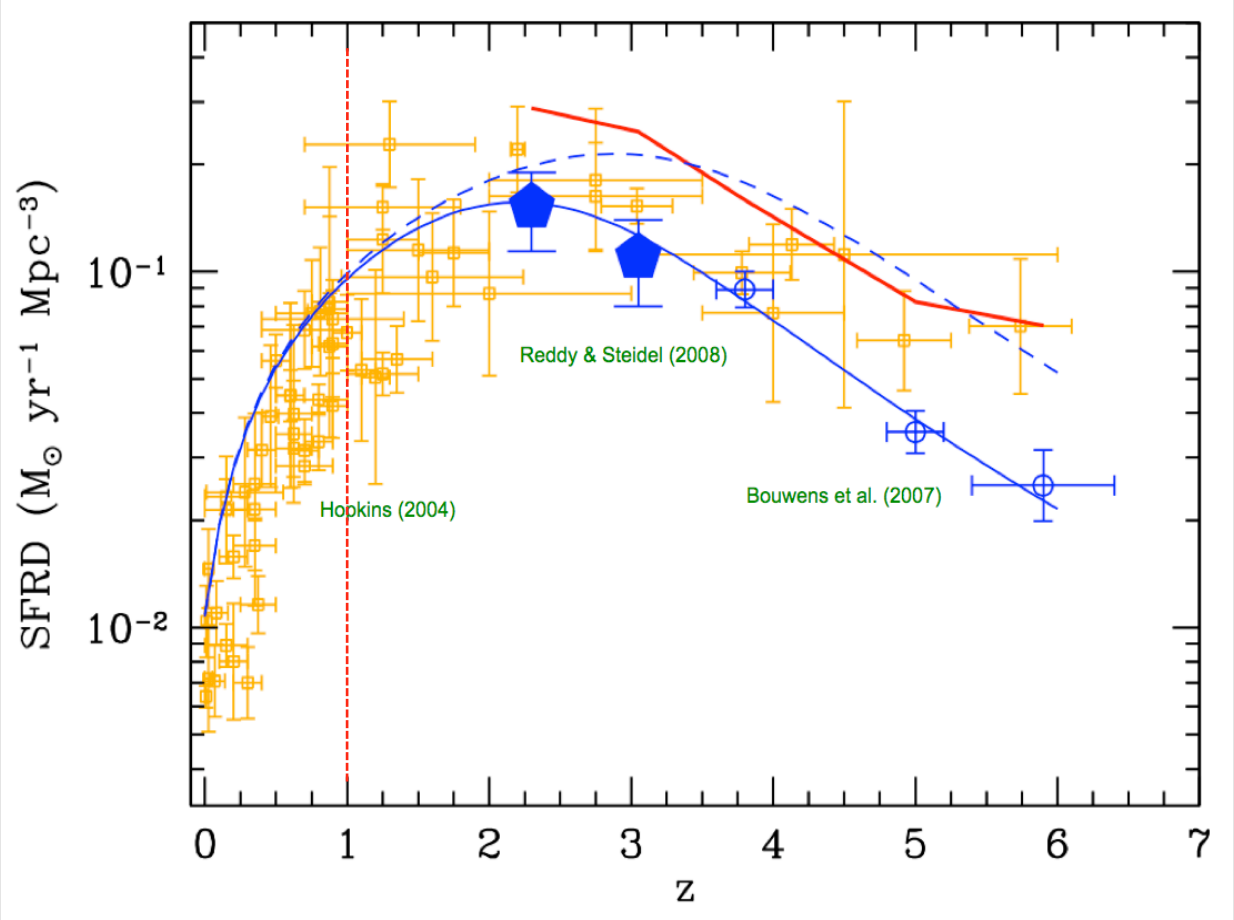
The Chandra Deep Fields





Galaxy Formation Era at $z \sim 1$-3

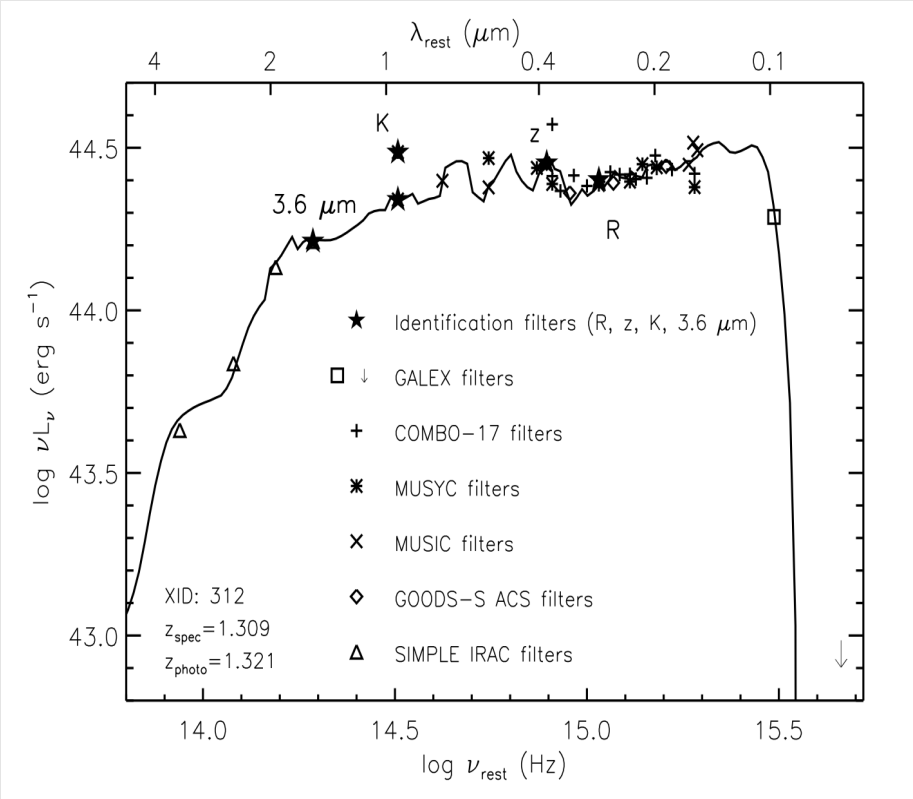
Cosmic Star-Formation History



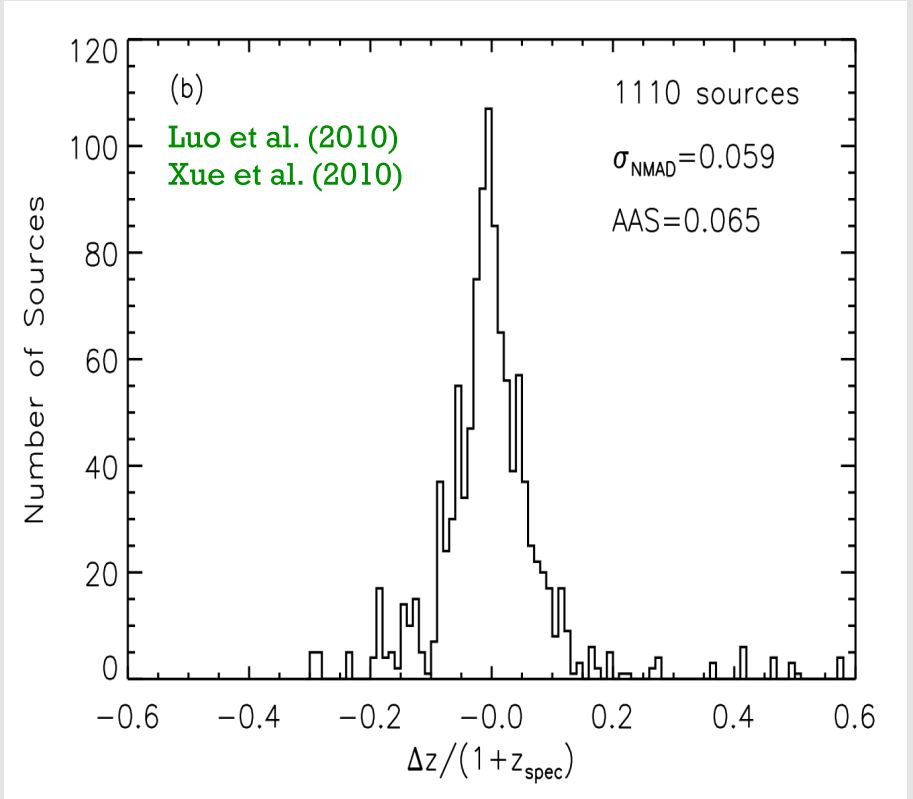
But many of the sources at $z \sim 1$-3 are too faint for spectroscopy ($R \sim 23$-26).

Good Photometric Redshifts to $R \sim 26+$

Example IR-to-UV SED with Fitted Template (Typically 15-35 Bands)

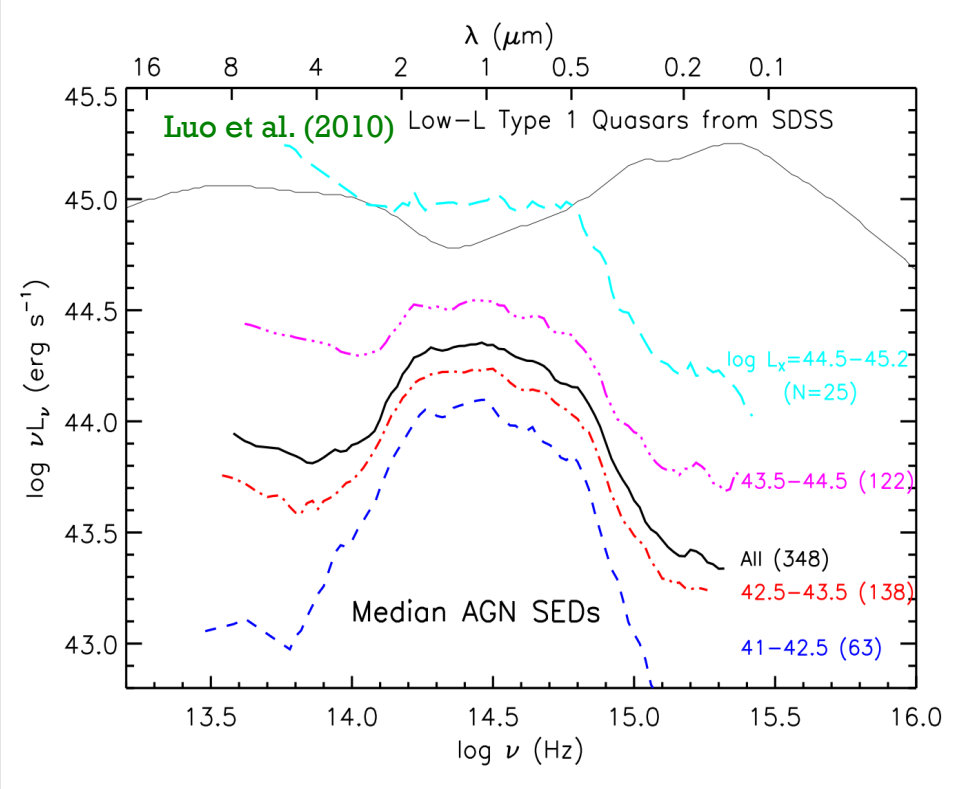


"Blind-Test" Assessment of Photo-*z* Accuracy

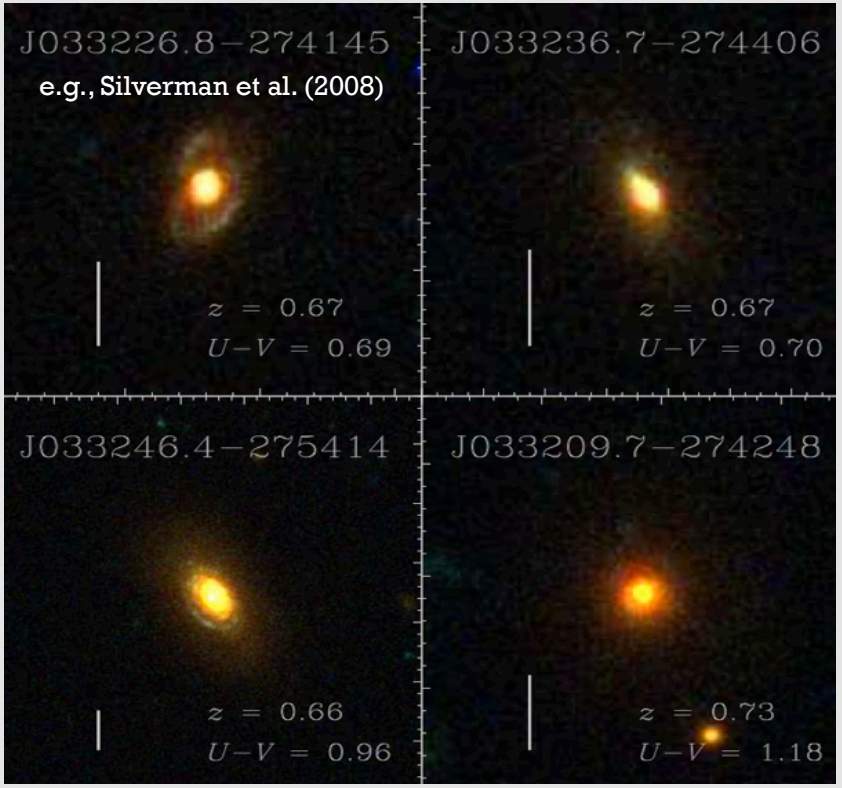


Feasibility of Host-Galaxy Measurements

Median AGN SEDs in Chandra Deep Field-South



HST Imaging of AGNs in CDF-S



Many X-ray AGNs have optical-to-submm emission dominated by host light.

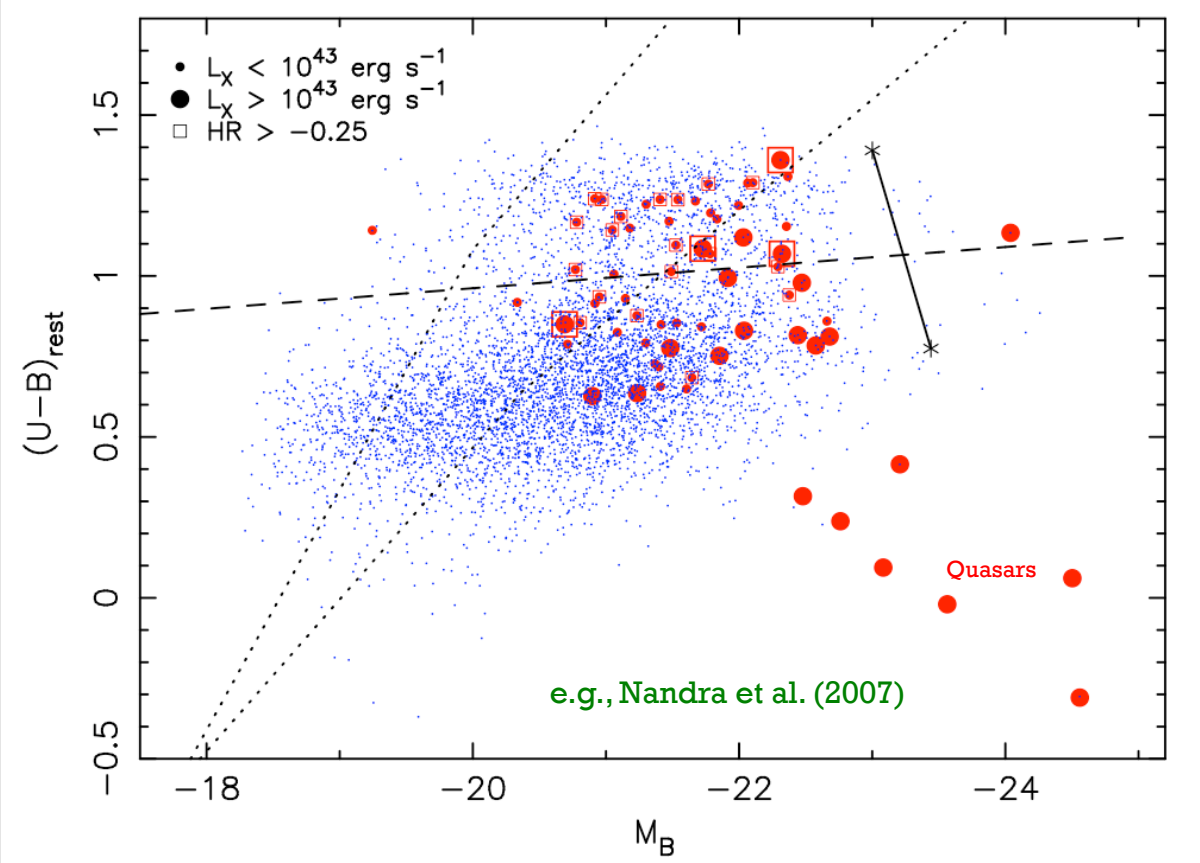
Also confirmed by HST imaging studies.

Can measure host morphology, color, stellar mass, star-formation rate, etc.

Color-Magnitude Relations

Apparent Clustering of AGNs in the Color-Magnitude Diagram

CMD with AGNs Marked as Large Dots (z = 0.6-1.4)



AGN hosts have broad color range, peaking in "green valley" or "red sequence".

AGN playing a role in transitioning galaxies from blue cloud to red sequence via "quenching" of star formation?

Rejuvenation of bulge-dominated systems by addition of a gas-rich disk over cosmic time (e.g., Hasinger 2008)?

Problems in sample construction (e.g., Silverman et al. 2009)?

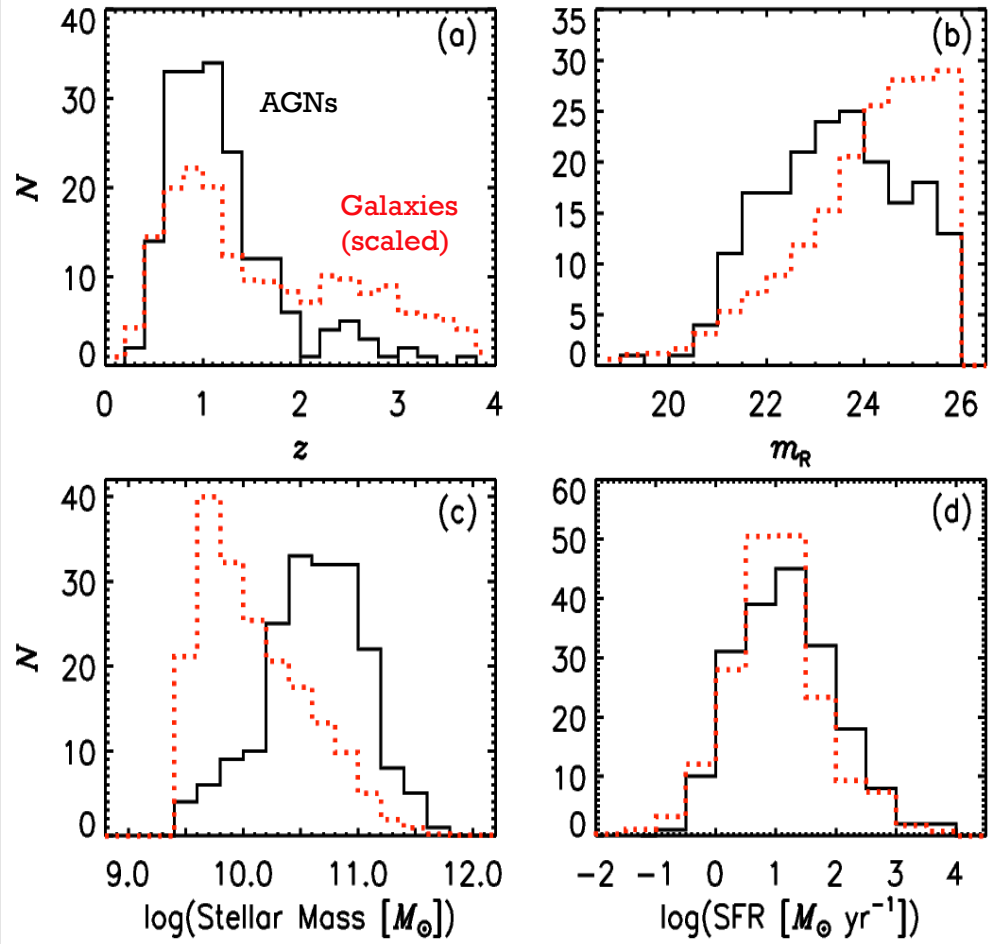
Aims of Present Chandra Deep Fields Work

Push CMD studies to higher redshifts (z = 1-3).

Relate our CMD studies to galaxy physical parameters (e.g., mass, star-formation rate).

Sample Physical Properties

Measured Physical Properties for 188 AGNs
and 4940 Galaxies in Central CDFs (to $R = 26$)



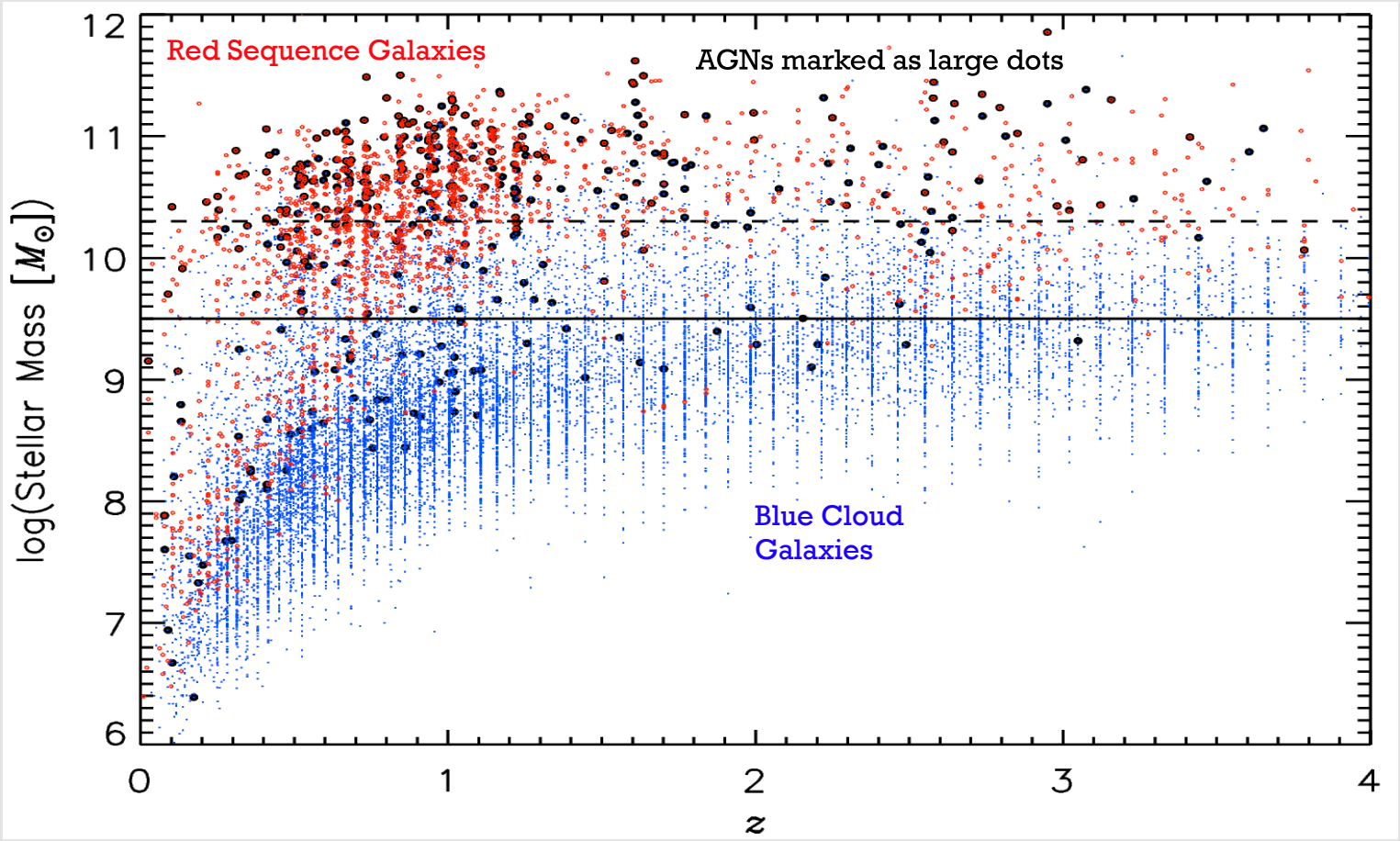
Galaxy masses determined from rest-frame *K*-band luminosities (via template SED fitting).

AGNs live in massive galaxies.

SFRs determined from UV and infrared luminosities.

Xue et al.

Stellar Mass vs. Redshift



Xue et al.

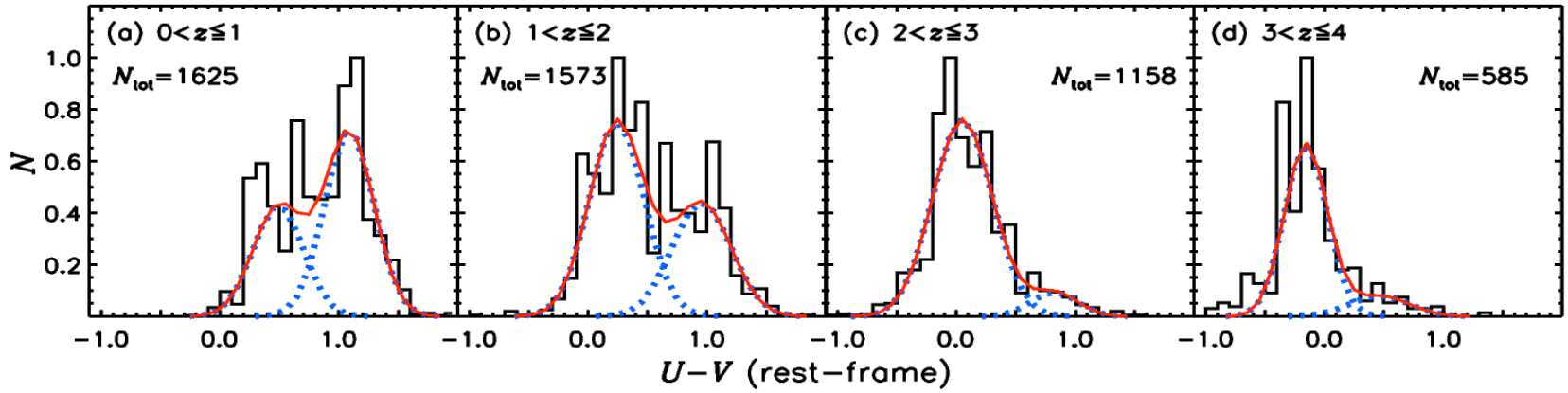
Two mass cuts adopted in sample definitions:

$10^{9.5}\,M_\odot$ – completeness limit for blue-cloud galaxies (188 AGNs, 4940 galaxies)

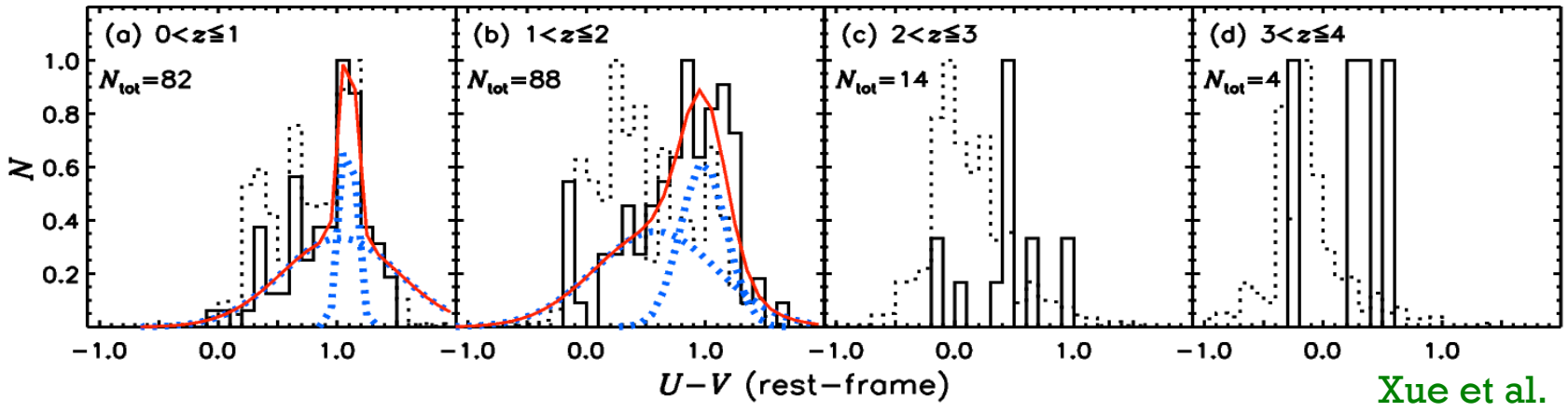
$10^{10.3}\,M_\odot$ – completeness limit for red-sequence galaxies (139 AGNs, 1470 galaxies)

Rest-Frame Color Distributions

Non-AGNs: Color Bimodality Seen to $z \sim$ 2-3 (including with dust corrections)



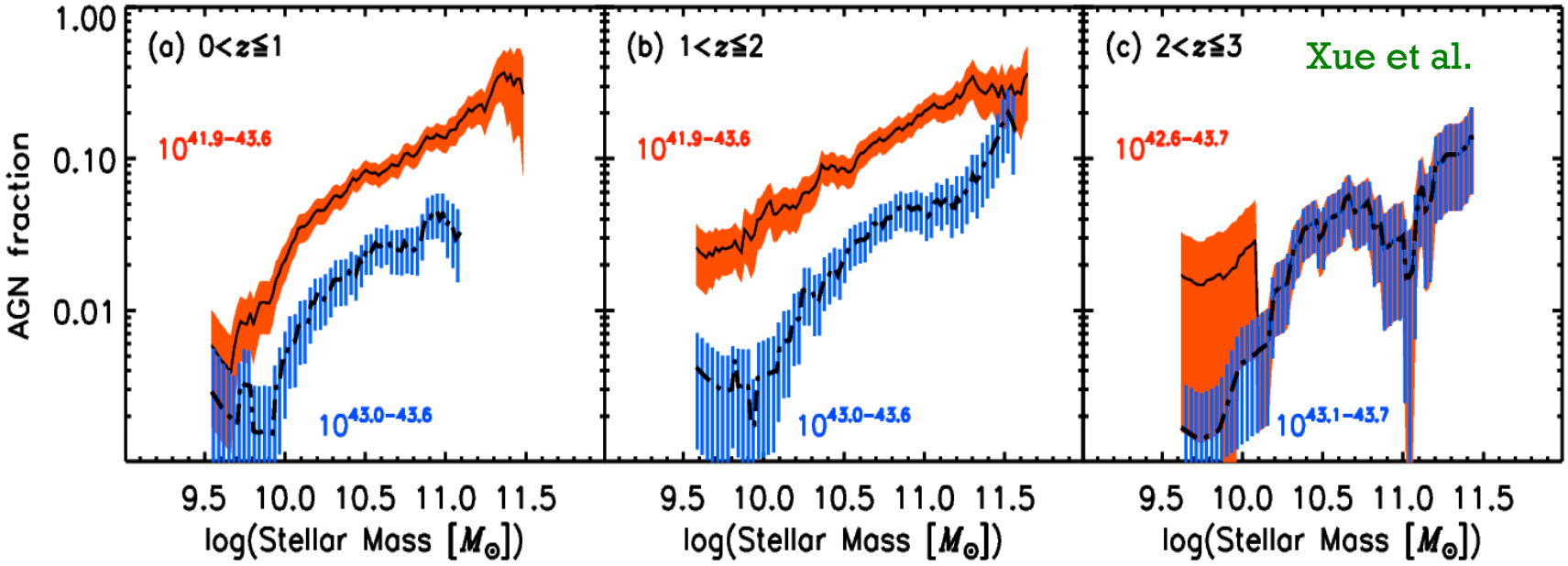
AGNs: No Detectable Color Bimodality for $z \sim$ 0-2



Xue et al.

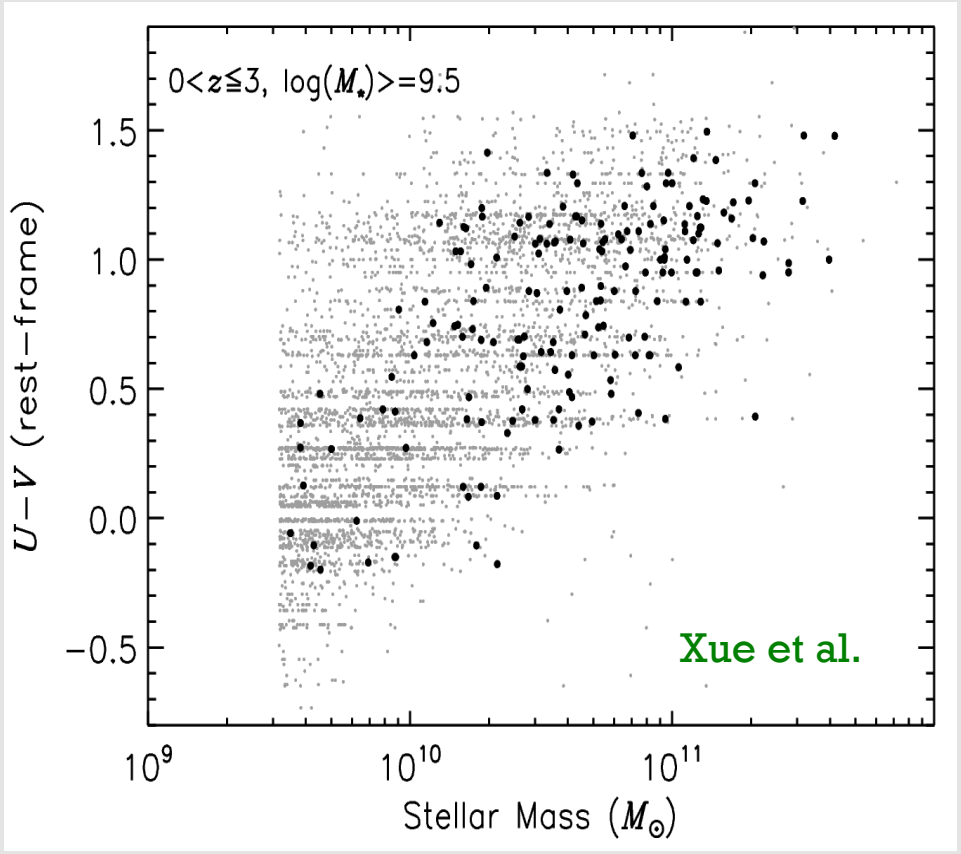
AGNs Prefer Massive Hosts to $z \sim 2$-3

AGN Fraction vs. Stellar Mass for Two X-ray Luminosity Classes



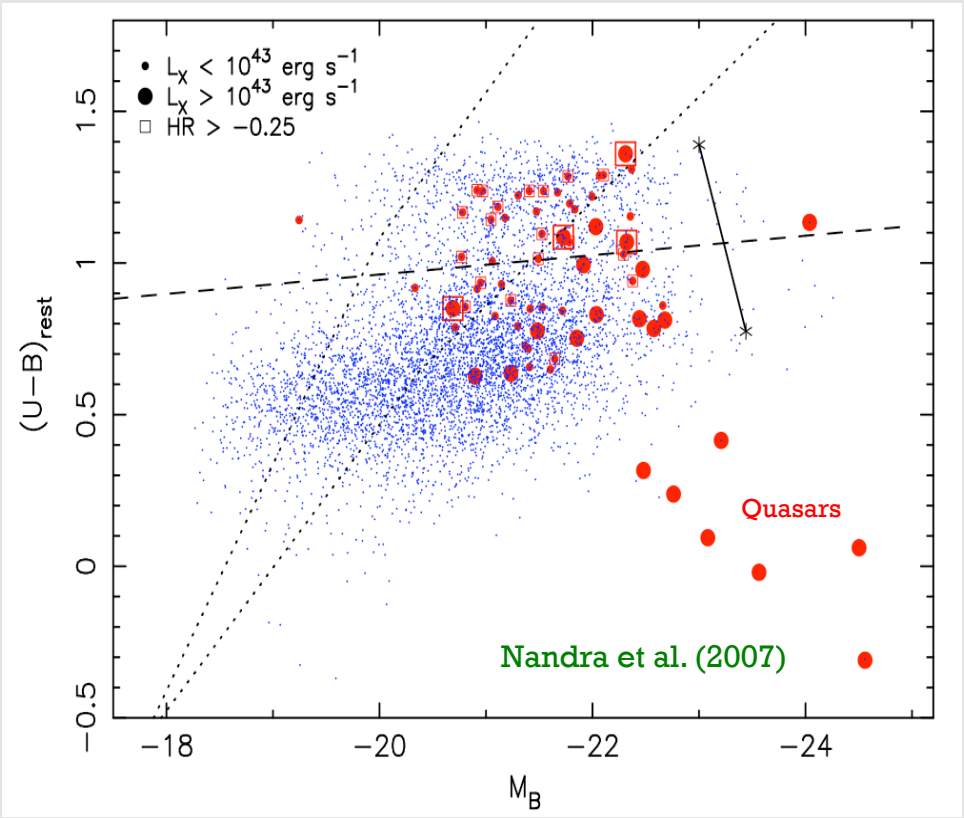
AGNs: Is it Color or Mass?

Color vs. Mass Relation

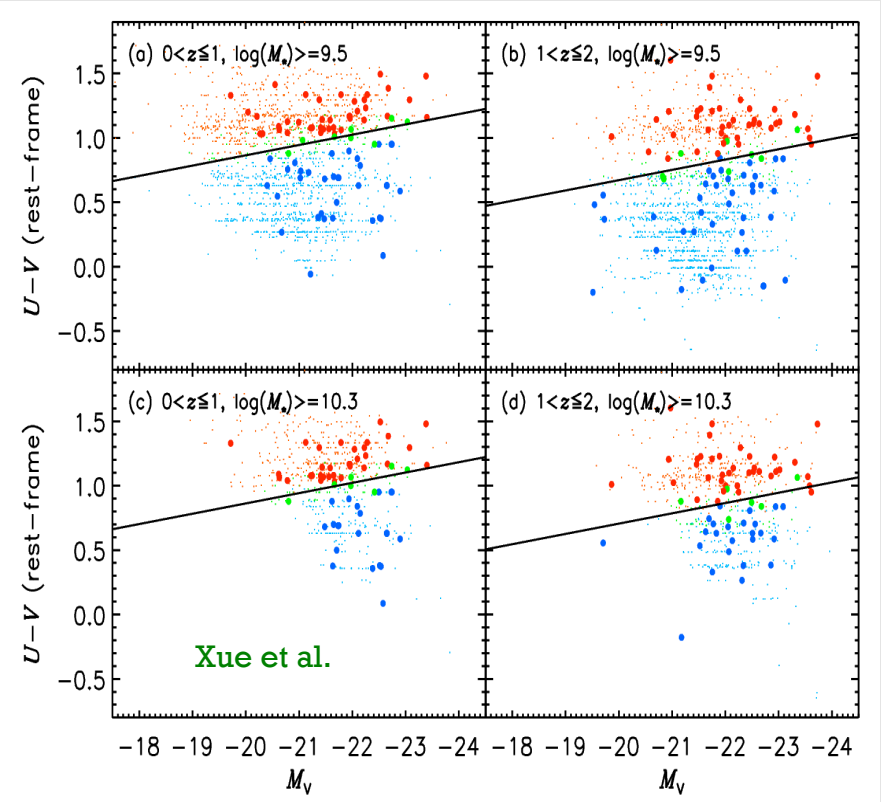


No Real AGN Clustering in CMD When Comparing Apples-to-Apples?

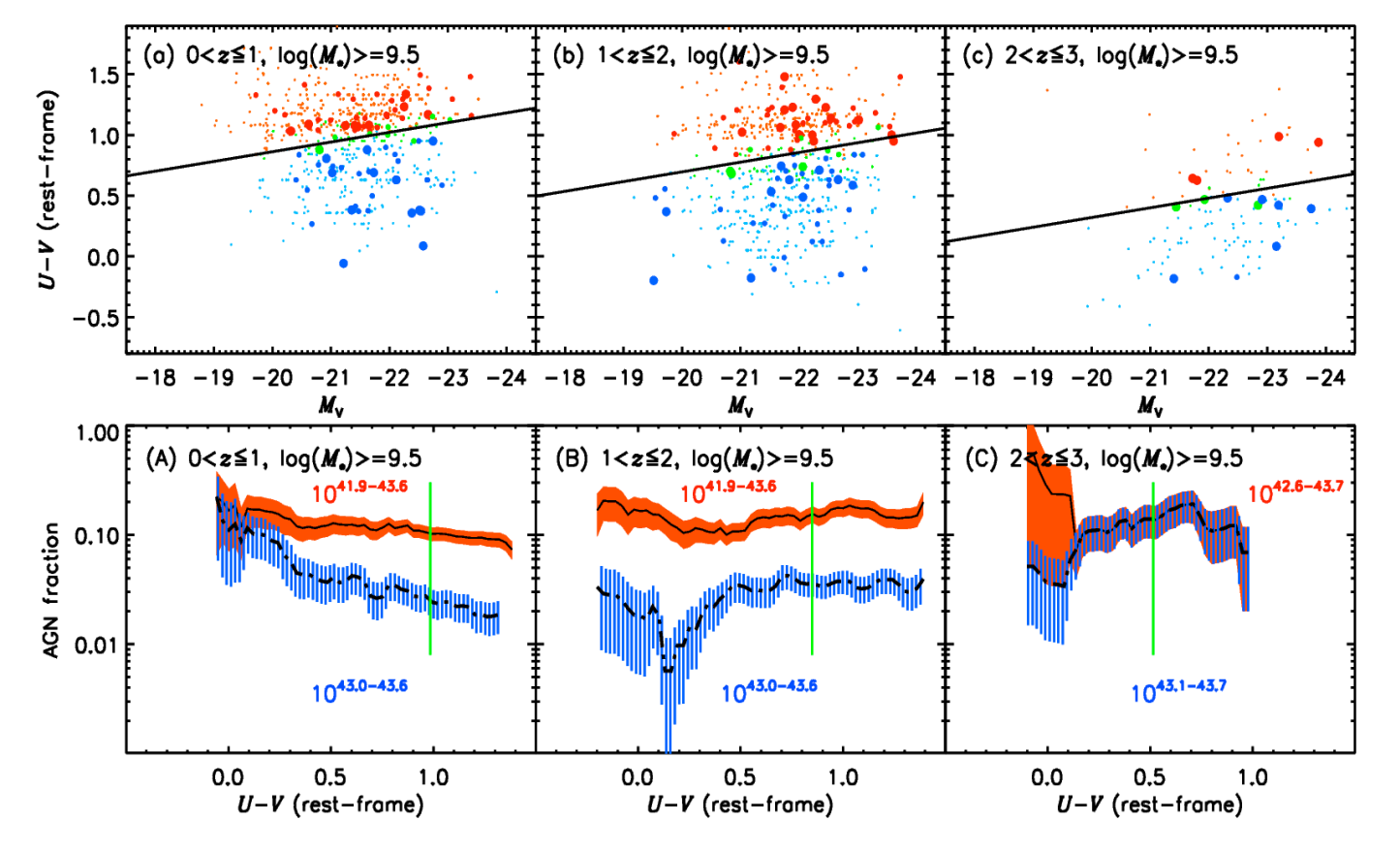
CMD with AGNs Marked as Large Dots (z = 0.6-1.4)



CMDs for Mass-Selected Samples



Mass-Matched Sample Results



Xue et al.

Constructed a mass-matched sample via random draws from galaxy population.

AGNs no longer occupy a distinctive location in the color-magnitude diagram.

AGN fractions flat or declining toward red colors.

Implications

After accounting for galaxy mass, no evidence for special clustering of AGNs in CMDs through most of galaxy formation epoch.

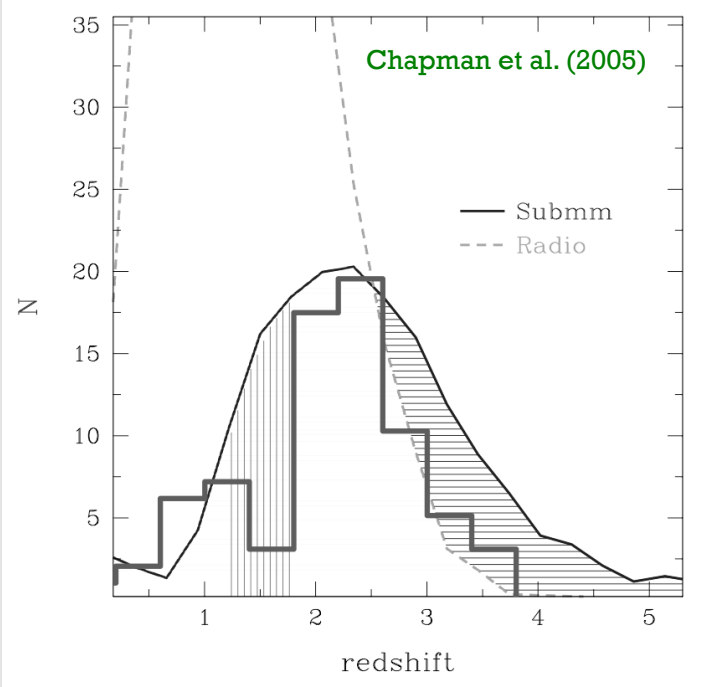
Previous claims about moderate-luminosity AGNs driving the color migration from the blue cloud to red sequence need to be re-assessed.

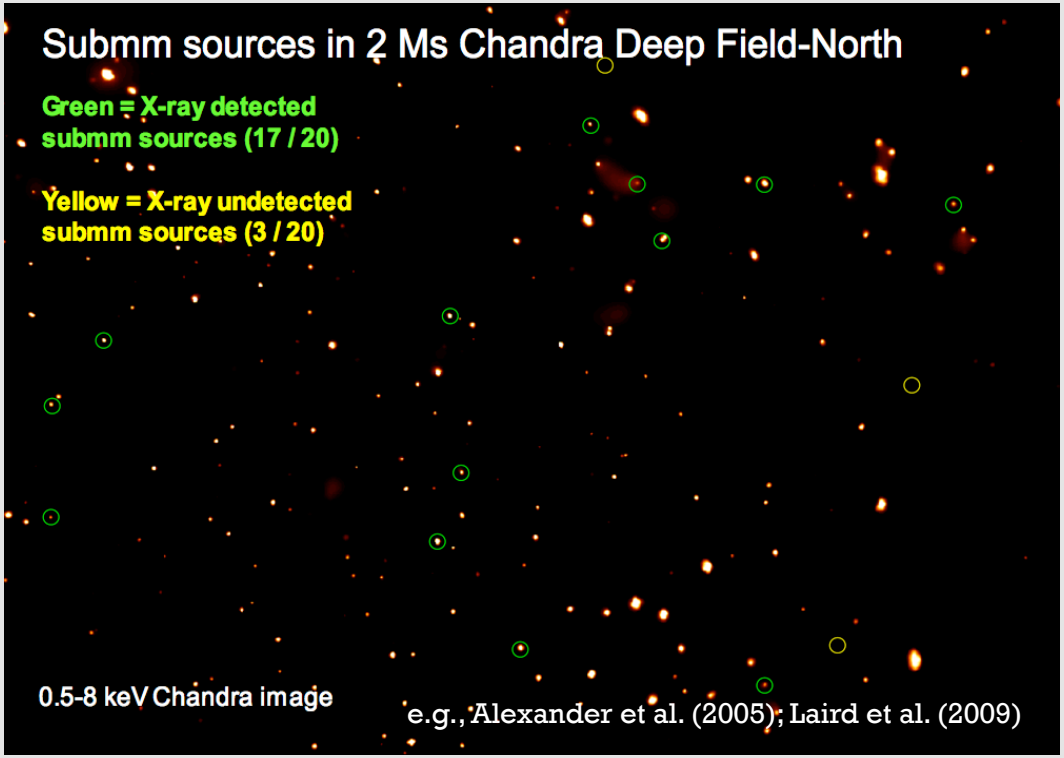
If AGN feedback has a role in driving the galaxy color migration, probably must occur in more luminous AGNs.

SMBH Growth in Distant Star-Forming Galaxies

X-ray AGNs in Submm Galaxies

Redshifts of CDF-N Submm Sources





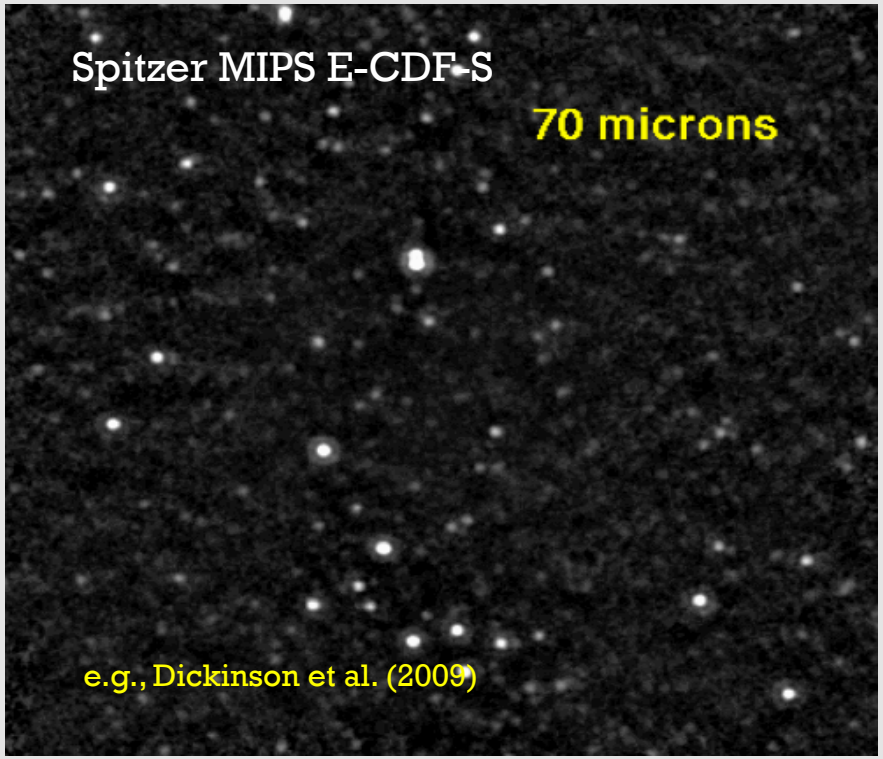
A remarkably high fraction of submm galaxies at $z \sim$ 1-4 are detected as X-ray sources in the deepest X-ray surveys.

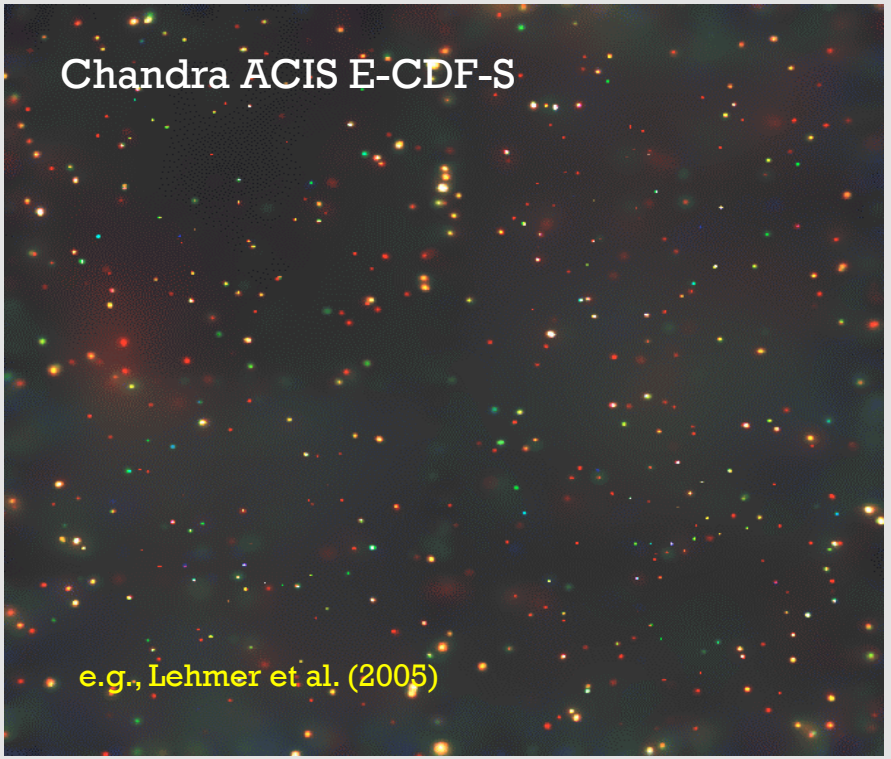
Often evidence for AGN activity. AGN fraction ~ 20-35%.

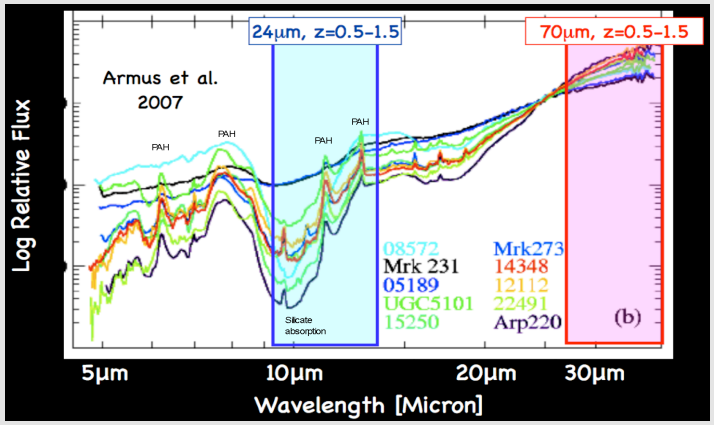
Suggests high duty cycle of SMBH growth in forming spheroids.

But submm samples small, difficult to use reliably, and only probe highest SFRs.

Use of Spitzer FIDEL + Chandra







Also used Spitzer FIDEL + Chandra for AEGIS.

In total, 1024 reliable sources at 70 μm.

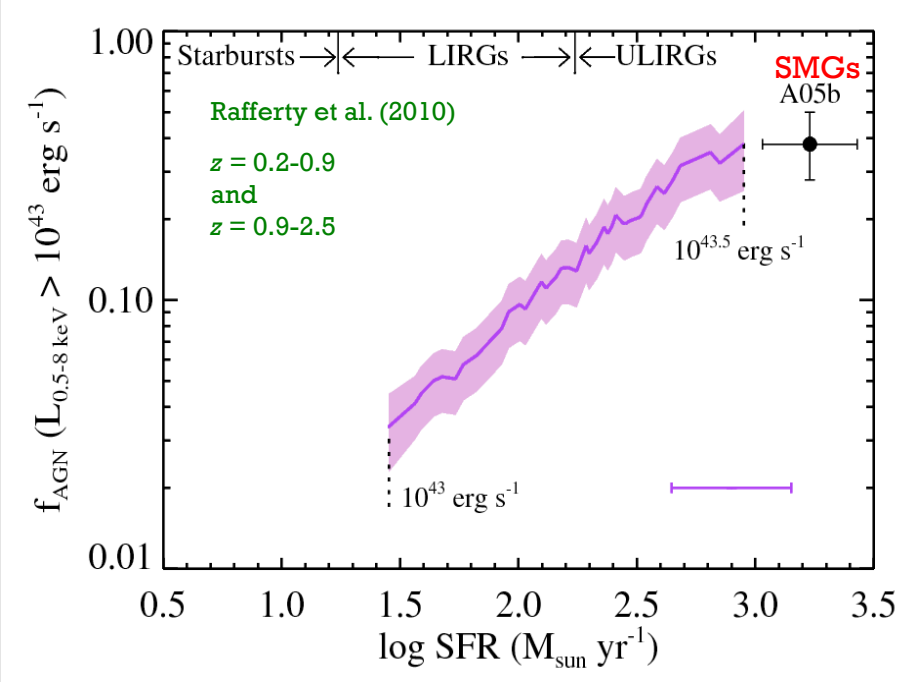
Identify 105 X-ray AGNs.

Estimate and remove AGN contribution at 70 μm (usually < 10-30%).

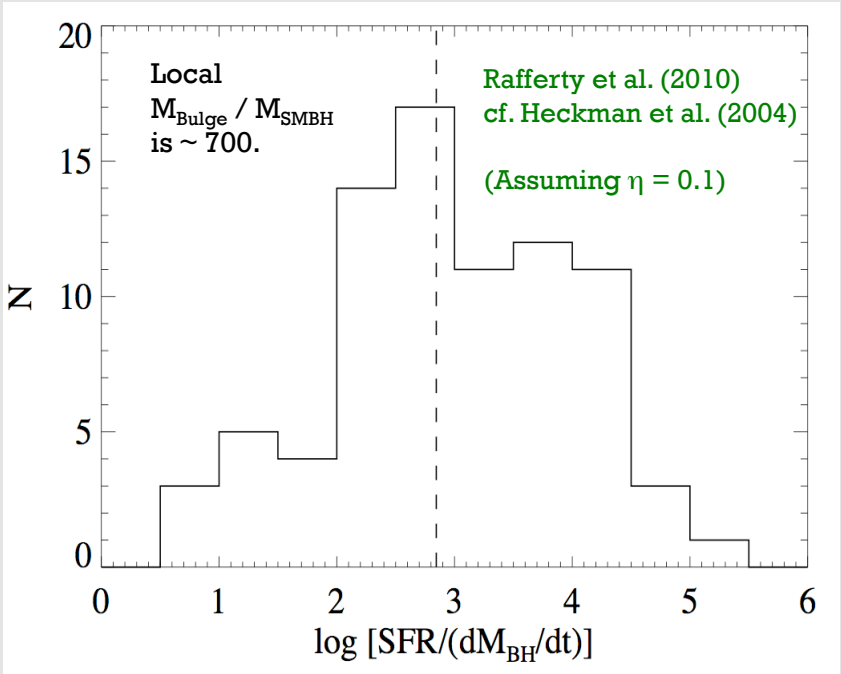
Then can derive SFR and AGN fraction.

AGN Fraction in Distant Star-Forming Galaxies

AGN Fraction for $L_X > 10^{43}$ erg s^{-1}



Ratio of Galaxy Growth Rate to SMBH Growth Rate



Distant X-ray AGN fraction increases with SFR, reaching 30-40% at highest SFRs.

Extends submm galaxy results with better statistics + different fields and methods.

SFR / (SMBH growth rate) broadly agrees with local M_{Bulge} / M_{SMBH} (large scatter).

Will be exciting to extend this work in the near future with Herschel.

The End